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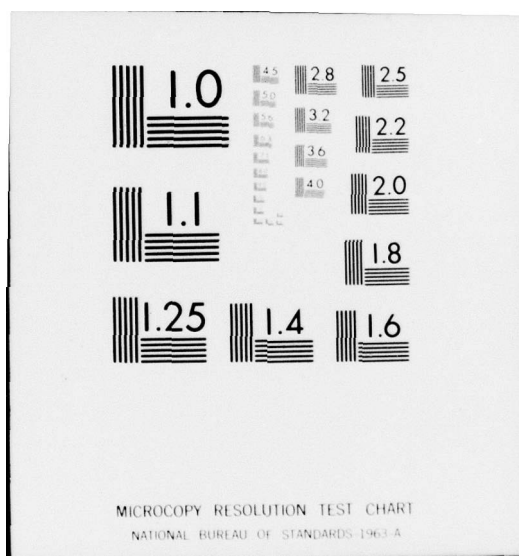
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1. INTRODUCTION

Two new fuzes under development at the Harry Diamond Laboratories (HDL) utilize hybrid integrated circuits (IC's), the XM587/724 Electronic Time Fuze and the XM734* Multi-Option Mortar Fuze. The question has been raised as to what the capability of industry is for volume production of hybrid IC's. The present goal for the XM734 program, for example, is for a production line to be built during FY77 and FY78, with production scheduled to begin at the end of FY78, leading up to a production rate of 100,000 fuzes per month.

The model used for this survey was the XM734 fuze amplifier. It contains two IC's, eight diodes, one Darlington transistor pair, one SCR, ten capacitors, one impact switch, printed resistors, and one ceramic substrate.

The U.S. Army Electronics Command (ECOM) initiated a manufacturing methods and technology program in 1973 to prove that automated techniques for hybrid-IC fabrication are feasible. Then ECOM funded RCA of Burlington, MA, to set up automatic equipment for a hybrid IC to demonstrate automatic wire bonding, automatic printing, automatic substrate handling, automatic chip and die placement, etc. The XM734 amplifier was chosen as a model for this demonstration line. That demonstration program has been completed, and approximately 3000 amplifiers were built by RCA under the program. Also, RCA demonstrated the feasibility of each piece of automated equipment necessary to build an automatic line. The demonstration was successful, and there is no question now that an automatic line is indeed feasible. The question that led to the survey reported in this paper, however, was whether or not hybrid IC's are being produced in quantities of 100,000 circuits per month or greater in the United States at the present time. The corollary questions are if they are being produced at high volume, is automation being used, and which techniques are preferred?

2. SURVEY METHODS

This survey utilized three major sources of information: a literature search, a telephone survey, and actual plant visits. The most significant information in the literature survey came not from the professional journals but from the so-called "throw-away" trade publications. Hybrid IC production techniques are rapidly changing. The digital wristwatch and the electronic ignition system, which

**Type classification of the XM734 fuze is expected in February 1977; its name will change to M734.*

account for such high-volume productions today, did not even exist a few years ago and are just now building up into volume production rates similar to those that we are contemplating for these fuzes. According to Electronics,¹ more than 200 million mechanical wristwatches were sold worldwide in 1975, while less than 4 million digital wristwatches were sold that year. The makers of digital wristwatches expect their market to increase to something like 90 million per year by 1980. Since the market did not exist three years ago, it is a rapidly expanding field and one in which technology is changing quickly. Another fertile source of information was the advertisements by the hybrid-IC manufacturers in the throw-away journals.

As the list of candidate companies was being built up, telephone interviews were begun. Over 20 different companies were called. They were asked detailed questions about their production capabilities and plans. Written telephone logs of the conversations are on file at HDL, but because of the proprietary nature of the answers, the results of the telephone conversations are included in this report only in a general way and without specific reference to the answers given by a particular company. The companies are listed in table I.

Finally, a few companies were selected for visits to educate the members of the survey team and to clarify the definition of "high-volume production" used in some of the telephone conversations. Many different circuit types can be included in the phrase "hybrid circuit." Any circuit using different technology types combined into one can be called a hybrid circuit. Since the survey team was interested in a very specific type--namely, a complex circuit involving active components, capacitors, and printed resistors on a ceramic substrate--the team wanted to make sure that its definition was the same as that being used by the manufacturer. Twelve hybrid-IC manufacturers's plants were visited. This number by no means included all the volume producers of hybrid IC's in the country. Because of the urgent nature of this survey, with production of the XM734 fuze line beginning in the fall of 1977, plant tours of all potential producers could not be made in the time necessary to publish this survey. Being left out of the survey by no means is an indication of lack of ability on the part of a manufacturer.

¹Electronics, 49, No. 12 (10 June 1976), 92.

TABLE I. COMPANY CODES

COMPANY	LOCATION	V T C
ALLEN-BRADLEY	MILWAUKEE WISC	N N 5
AMERICAN MICROSYSTEMS	SANTA CLARA CALIF	N Y 4
ANALOG DEVICES	NORWOOD MASS	N Y 3
BALDWIN ELECTRONICS	LITTLE ROCK ARK	N Y 3
BECKMAN INSTRUMENTS	FULLERTON CALIF	Y Y 1
BURR BROWN	TUSCON ARIZ	N Y 4
CENTRALAB ELECT	MILWAUKEE WISC	N Y 4
CIRCUIT TECHNOLOGY INC	FARMINGDALE NY	N N 3
COLLINS RADIO	DALLAS TEXAS	N Y 2
COMPOSITE MICROCIRCUIT	BURLINGTON MASS	N Y 2
CTS MICROELECTRONICS	WEST LAFAYETTE IND	N Y 3
DATTEL SYSTEMS	CANTON MASS	N Y 4
DELCO ELECTRONICS	KOKOMO IND	N N 1
FAIRCHILD SEMICONDUCTOR	MOUNTAIN VIEW CALIF	Y Y 1
GARRETT MICROCIRCUITS	ONTARIO CANADA	N N 5
GENERAL ELECTRIC	LYNCHBURG VA	N N 5
GENERAL ELECTRIC	PHILADELPHIA PA	N Y 3
GENERAL INSTRUMENTS	HICKSVILLE, NY	Y N 3
HONEYWELL	PHOENIX ARIZ	N Y 4
HONEYWELL	ST PETERSBURG FLA	Y Y 3
HUGHES AIRCRAFT	NEWPORT BEACH CALIF	Y Y 1
HYBRID SYSTEMS	BEDFORD MASS	N Y 4
IBM	? ? ?	N N 5
ILC DATA DEVICE CORP	BOHEMIA NY	N Y 3
MAGNOVOX	FT. WAYNE IND	N Y 3
MICROELECTRONICS INC	ALDEN NY	N N 5
MICROPAC	GARLAND TEXAS	Y Y 2
MOTOROLA	FT LAUDERDALE FLA	N N 5
MOTOROLA	FRANKLIN PARK ILL	Y Y 1
MOTOROLA	PHOENIX ARIZ	N Y 4
NATIONAL SEMICONDUCTOR	SANTA CLARA CALIF	Y Y 1
OPTIMAX	PHILADELPHIA PA	N Y 3
RAYTHEON	QUINCY MASS	Y Y 2
RCA	BURLINGTON MASS	Y N 3
ROCKWELL AUTONETICS	ANAHEIM CALIF	N Y 4
SPRAGUE	NORTH ADAMS MASS	N N 5
STEWART-WARNER	CHICAGO ILL	N Y 3
TELEDYNE MICROELECTRONICS	LOS ANGELES CALIF	Y Y 3
TEXAS INSTRUMENTS	DALLAS TEXAS	Y Y 3
ZENITH RADIO	ELK GROVE ILL	N Y 1

40 RECORDS

V = VISIT TO PLANT
T = TELEPHONE SURVEY
C = CATEGORY

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3. SURVEY ORGANIZATION

It was quickly determined that the hybrid-IC manufacturers of the country could be divided into different categories based on the type of markets they were in and were seeking. Since this became a convenient way to separate the manufacturers, the categories were defined carefully. This industry is a very dynamic marketplace, and companies are ever changing their goals and their position in the list of categories.

Category I.--The manufacturers in category I are presently producing hybrid IC's, as the survey team defines them, in volume production of more than 100,000 hybrid IC's per month.

Category II.--The manufacturers in category II are rapidly building their production rates toward the goal of 100,000 circuits per month or greater. They are expending their own money for production lines and expect to reach or exceed the goal by FY79. (NOTE: Companies may be in category II rather than III merely because they are more optimistic about pending contracts.)

Category III.--The manufacturers in category III are not in volume production of hybrid IC's, nor are they expending substantial sums to become high-volume producers of hybrid IC's. However, they are very much interested in producing fuze hybrid IC's in volume production and would willingly accept a contract from the Government to build a volume-production line. In general, they have little or no experience with very large productions of hybrid IC's.

Category IV.--The manufacturers in category IV were not interested in high-volume sales of hybrid IC's. Some of these companies specialize in precision high-reliability hybrid IC's, and they have no plans for expanding into volume production. Other companies in this category are in volume production of hybrid IC's but do it for their own use only and are not interested in producing hybrid IC's for customers. These companies may be of interest for mobilization-base programs, but since they are not interested in customers, they are unwilling to talk about their proprietary processes and their actual production levels.

Category V.--The manufacturers in category V have unknown capabilities. They are in this category because the time limitations of this survey prevented a detailed investigation of their capabilities. Category V includes all companies in the country producing hybrid IC's which are not included in one of the other four categories. Some of these companies are likely to be volume producers of hybrid IC's but

were left out of the survey because of their geographical location or some quirk associated with the survey. No attempt will be made to make a listing of all the possible companies that would fit into this category.

4. SURVEY RESULTS

Automation is being used, and it is a reliable cost-effective method. However, where cost is the major consideration in a rapidly evolving competitive situation, much of the production is done by hand in "overseas" plants as a cheaper alternative to mechanization. The digital wristwatch makes a good illustration of this point. Since, competition is fierce in both technical innovation and cost reduction, manufacturers are ever striving to lower the cost and to add new features to their products. Automation, therefore, has been limited to those techniques which permit modifications to be made easily and rapidly to the product. The typical digital wristwatch contains a hybrid IC printed on an automatic printer in the United States. The printed substrate is then shipped to a plant in Mexico or the Far East for component attachment and wire bonding. The subassembly is then shipped back to the United States for automatic laser trimming and automatic testing. On the other hand, a complex hybrid IC in volume production in a relatively stable market was being produced wholly in this country, using all automatic production gear including automatic wire bonders, automatic pick-and-place units for the components, automatic laser trimming, and automatic printing.

Those automatic production techniques which require large tooling investments seem to be reserved for use for very large volume production levels, perhaps those exceeding 1 million circuits per month. Each company seems to have a favorite volume-production technique and many reasons why other techniques are not used. There is no consensus, however, as to which are the best techniques. The opinions expressed by the manufacturers are so strong, that it is suspected that, by selecting a particular contractor to design a circuit for production, one would, in fact, be selecting a manufacturing technique.

When asked how they would like to approach a volume-production job such as HDL's, there was general agreement that the companies would like to spend 3 to 6 months analyzing the circuit layout and designing their production procedures. During this introductory period in the ideal program, they would redesign the circuit layout to reduce the number of printings and to increase the yield of the printings. They would select new capacitor types for lower cost and ease in automated handling. At the end of this introductory period, they would begin production at a

very low rate, perhaps 100 hybrid IC's in the first month. They would then continue production, doubling the rate each month until they reached 4000 hybrid IC's per month. During this time, the engineering staff would be looking for production difficulties and deciding where the maximum benefit from automated production equipment would be. Before production exceeded 5000 circuits per month, the wire-bonding and component-placing functions would be switched to the overseas production facility. The U.S. production engineer would go with the hybrid IC and stay in the foreign plant for a month or two as the production rate built up. Under the ideal plan, production would reach 100,000 units per month before the end of the first year. No time is allowed in this ideal plan for purchase of equipment and tooling. The reason is that most of the equipment already exists, and the only job necessary would be to program the automatic testers and trimmers and handling equipment for getting substrates in and out of the automatic production equipment.

Most of the companies would be willing to consider setting up a fully automated, dedicated production line for the XM734 hybrid amplifier. They would not, however, normally automate fully, and they would consider full automation unnecessary for peacetime production. Those companies more familiar with military and Government buying sometimes could point to an idle, Government-owned, production line and were familiar with the reasons for having such a line. They pointed out, however, that an automated line developed before production began would perhaps include more automation and more equipment than might be necessary if the automated line were developed concurrently with a buildup of production.

Therefore, there are quite a few possibilities for the purchase of a fuze hybrid IC. The technique considered most normal by the volume producers of hybrid IC's would be a multiyear fixed-price contract for a number of amplifiers. The contractor would supply all the tooling and equipment necessary to build the amplifier. Part of the production would be done overseas, but using a value-added basis, this overseas work would be a very small portion of the total cost of the amplifier.

The other extreme would be the totally automated turnkey production line dedicated to the XM734 amplifier. This entire line would be assembled before the first amplifier was built and, when turned on, would produce 100,000 amplifiers per month using a one-shift operation. The purchase of amplifiers could be separate from the purchase of the automated production line. In fact, considering our peacetime need for economical production and our mobilization need for automation, this possibility might be the best for HDL. There are collections of candidate systems in between these two, such as an automated line that is only partially used.

Conversations with the manufacturers revealed that there may be contractual difficulties with trying to buy a large number of amplifiers with a series of 1-year contracts. The large-volume hybrid IC manufacturers have rather small engineering staffs. Thus, they are reluctant to take on production jobs that may require the use of a full-time engineer for 6 months if there is not a high certainty that the production job will continue for several years. Also, the negotiation for the second year of a 3-year procurement would have to be underway before any hybrid IC's were produced under the first year's procurement. Thus, production experience from the first year would not be of any use for the negotiations for the second year.

Another difficulty is that the manufacturers are going to favor producing part of the fuze overseas instead of using a totally automatic line in the United States. They claim that there is a 5-to-1 cost difference in manufacturing labor between overseas and the United States and that the automation techniques available are not good enough to offset this difference in labor costs. If the assembly of an automated production line were separated, contractually, from the purchase of several million amplifiers, the situation could arise in which the automated line would sit idle in this country while the amplifiers would be produced, at least in part, by an overseas manufacturer.

5. CONCLUSIONS

This survey shows that hybrid IC's similar in complexity to those used in the XM587 and XM734 fuzes are in volume production. Many companies in the United States would accept a fixed-price contract for the purchase of XM734 amplifiers at production rates exceeding 100,000 per month. The price of the amplifier as presently designed would be in agreement with those prices formally estimated by HDL in the XM734 cost estimate.

Certain types of automation are widely used. Nearly all of the volume producers visited were using some form of automatic substrate printing. Computer-controlled laser trimmers for active and passive trimming of resistor values are widely used. Automatic wire bonders and automatic component placing equipment are used in volume production in the United States, but there is some question as to whether automation is competitive with doing the same work overseas manually. The more exotic automation techniques such as the widely discussed filmstrip technique are available for production and have been used on some jobs, but exotic automation is not the preferred method for the

companies in category I. Automation techniques which are sensitive to details of the circuit design, such as filmstrip techniques and custom IC's, are avoided wherever possible by producers in competitive markets. Their reasoning is that techniques involving lengthy equipment setup times do not allow them to take advantage of component price changes.

Great care should be exercised in the selection of a contractor to study or recommend production techniques. Such strong opinions are held by some manufacturers about automation techniques that selection of a contractor may indeed be a selection of a technique as well.

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